Re-considering the Appropriate Risk Level for Anchovy in OMP-13 Development

C.L. de Moor* and D.S. Butterworth*

Correspondence email: *carryn.demoor@uct.ac.za*

Introduction

The acceptable level of risk changes from one MP to the next given changes in the perceived level of productivity of a resource resulting from the inclusion of revised and new data in the underlying operating models. This is because the more or less the abundance of an unexploited resource fluctuates naturally (see, for example, the biomass distributions in the absence of catches that are implied by different operating models which are shown in Figure A.1), the more or less resilient it is likely to be to reduction to a specified level through exploitation, and hence the greater or lesser the acceptable probability that fishing reduce the resource to below that level. de Moor and Butterworth (2010) developed an objective method for determining an acceptable level of risk for a new MP that maintained comparability with that adopted in selecting the previous MP. This method was applied to obtain a revised level of risk for sardine in developing Interim OMP-13 (de Moor and Butterworth 2012b). However, the application of this method to obtain a revised level of risk for anchovy for Interim OMP-13 was not straightforward given changes (supported by analyses of updated time series of data) in the selected natural mortality values and stock-recruitment relationships from the operating model used to develop OMP-08 (de Moor and Butterworth 2012a).

Based on work by de Moor and Butterworth (2012a), Interim OMP-13 (de Moor and Butterworth 2012b) was chosen as the corner point of the trade-off curve which was tuned such that each point on the curve satisfied $risk^S < 0.21$ and $risk^A < 0.20$, where the definitions of risk remained unchanged from OMP-08:

$risk^S$ - the probability that adult sardine biomass falls below the average adult sardine biomass over November 1991 and November 1994 at least once during the projection period of 20 years.

$risk^A$ - the probability that adult anchovy biomass falls below 10% of the average adult anchovy biomass between November 1984 and November 1999 at least once during the projection period of 20 years.

The anchovy assessment was considered by the Review Panel of the 2012 International Fisheries Stock Assessment Workshop, who noted that the assumptions used in the base case operating model on which

* MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.

OMP-08 was developed, of $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$ and a Hockey Stick stock recruitment relationship with fixed inflection point, were not supported by the data and assumption that catchability of the recruit survey being less than for the November biomass survey (k_r^A / k_N^A). They also noted the increase in risk to the anchovy resource when moving from an assumption of $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$ with a Hockey Stick stock recruitment relationship with fixed inflection point to $\overline{M}_j^A = \overline{M}_{ad}^A = 1.2\,\text{year}^{-1}$ with a Beverton Holt stock recruitment relationship for the same OMP control parameters (Smith *et al*. 2012; Table A.2).

Following the spirit of the suggestions by the Review Panel (Smith *et al*. 2012) this document provides some further comparisons of anchovy risk levels between the alternative anchovy operating models under OMP-08 and Candidate OMP-13. Two alternative sets of operating model assumptions are considered:

"HS0.9" : a Hockey Stick stock recruitment relationship with a fixed inflection point of $b^A = 0.2K^A$ and $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$.

"BH1.2" : a Beverton Holt stock recruitment relationship with $\overline{M}_j^A = \overline{M}_{ad}^A = 1.2\,\text{year}^{-1}$.

Two alternative sets of data and associated assumptions are considered:

"2006 data" : Time series of survey estimates of November 1+ biomass from 1984-2006, survey estimates of recruitment from 1985-2006, egg survey estimates of absolute spawning stock biomass from 1984 – 1991, estimates of November proportions-at-age 1 from 1984-2006 obtained using an average 1992-1995 ALK; cut-off lengths for recruit catches vary by month, annual weights-at-age based on average 1992-1995 ALK (de Moor and Butterworth 2007 with further updates to data and results).

"2011 data" : Time series of survey estimates of November 1+ biomass from 1984-2011, survey estimates of recruitment from 1985-2011, egg survey estimates of absolute spawning stock biomass from 1984-1993, estimates of November proportions-at-age 1 from 1984-2011 obtained from the November survey length frequency distributions, cut-off lengths for recruit catches vary by year and month, annual weights-at-ages 1 and 2+, split further by age using a growth curve relationship (de Moor and Butterworth 2012c).

Operating Models

Although in 2006 BH1.2 provided a better fit to the data at the joint posterior mode than HS0.9 (Table 1 – see the AIC_c values), the latter was chosen as the base case operating model for the development of OMP-08, given the desire to keep key operating model assumptions unchanged from those used in selecting OMP-04. Figure 1 shows the model estimated stock recruitment curves for HS0.9 and BH1.2, using the 2006 data.

Using updated data, BH1.2 was chosen as the base case operating model for anchovy for the development of OMP-13 as the Beverton Holt stock recruitment curve provided a better fit to the Hockey Stick stock recruitment curve with a fixed inflection point (the fixed inflection point initially having been used when there were insufficient data to estimate the inflection point) and the lower natural mortality resulted in $k_r^A / k_N^A > 1$ (see Table 1 and caption thereof for details). Figure 2 shows the model estimated stock recruitment curves for HS0.9 and BH1.2, using the 2011 data.

Resource Risk

The control parameters for OMP-08 ($\alpha = 0.78$, $\beta = 0.097$) were chosen from the corner point of the trade-off curve which was constrained to satisfy $risk^A < 0.10$ and $risk^S < 0.18$. These risk levels were chosen to maintain a similar distribution of depletion of the resource under OMP-08 compared to a no catch scenario as had been assumed during OMP-04 development. In other words, the principle underlying this approach was that the "leftward shift" in the projected biomass distribution from a no catch to a MP scenario should be maintained from one OMP to the next (Figure A.2). As the shape of the distributions vary, it was decided to match the ratio of [MP : no catch] distributions at the 20th percentile as closely as possible (de Moor and Butterworth 2010, Table A.1).

In this document all comparisons between the "leftward shift" of projected biomass distributions are carried out for combinations of control parameters at the corner point of trade-off curves satisfying the chosen risk levels.

The ratios of the lower percentiles of the [MP : no catch] distribution for OMP-08 are given in Table 2 (column 1). If BH1.2 reflects the actual underlying dynamics, the *risk* statistic for anchovy would have been higher and that for sardine lower under OMP-08 (Table 3a, row 1). Furthermore the 20th percentile of the projected biomass distribution under OMP-08 would have been 14% of that under a no catch scenario, compared to 36% under HS0.9 (Table 2, column 3).

Given the same underlying operating model (HS0.9), this same method would result in risk levels of $risk^A < 0.12$ and $risk^S < 0.21$ for Candidate OMP-13 with $c_{mxtac}^A = 600$ (Figure 3, Table 2, column 2 and Table 3, row 2). Assuming a HS0.9 operating model, the resultant control parameters $\alpha = 0.782$,

$\beta = 0.067$ give an average projected directed sardine catch of 127 000t and an average directed[1] anchovy catch of 385 000t, 95 000t of which is assumed caught during the additional season (Table 3b). However, if this Candidate OMP-13 were applied, and reality was closer to the operating model BH1.2, then the model projects the average directed sardine catch to be 129 000t and the average directed anchovy catch to be 292 000t, 67 000t of which would be caught during the additional season (Table 3b), and a *risk* statistic that is more than double that of HS0.9 (Table 3a).

Alternatively Candidate OMP-13 could be tuned to the resultant leftward shift of OMP-08 under the BH1.2 operating model. This method would result in risk levels of $risk^A < 0.35$ and $risk^S < 0.21$ for Candidate OMP-13 with $c^A_{mxtac} = 600$, and $\alpha = 0.635$, $\beta = 0.082$ (Figure 3, Table 2, column 4 and Table 3a, row 3). The average projected directed sardine catch is 145 000t and the average projected anchovy catch is 289 000t, 69 000t of which is projected to be caught during the additional season. If, however, HS0.9 was closer to reality, then the model projects the average directed anchovy catch to be 362 000t, with 91 000t caught during the additional season (Table 3b). There is little change in the control parameters under the modification $c^A_{mxtac} = 450$ (Table A.3).

When comparing $risk^A$, $risk^S$, and average directed catches under other alternative hypotheses (results not shown here) the difference in results between stock-recruitment relationships is greater than the difference between $\overline{M}^A_j = \overline{M}^A_{ad} = 0.9\,\text{year}^{-1}$ and $\overline{M}^A_j = \overline{M}^A_{ad} = 1.2\,\text{year}^{-1}$.

Choice of Risk Level for Candidate OMP-13

If the ratios of depletion ("leftward shift") under OMP-08 are considered to have been acceptable under all plausible alternative hypotheses/population models (as is conventionally checked when considering the results from OMP robustness trials), including BH1.2 (i.e. Table 2, column 3), then one could defend the above comparative method to choose a risk level for OMP-13 (which, given BH1.2 and Candidate OMP-13 with $c^A_{mxtac} = 600$, would be $risk^A < 0.35$). However, there are a number of issues to consider

- BH1.2 was not a tested alternative hypothesis for OMP-08, and thus the ratios of depletion of OMP-08 under BH1.2 were not explicitly considered. (Alternative models BH0.9 and HS1.2 were tested in 2006.)
- Having now run OMP-08 under BH1.2, Table 1 gives AIC_c values which can be used as a qualitative[2] measure of model selection. Although BH1.2 is a better model with both "2006 data" and "2011 data", the difference in AIC_c between HS0.9 and BH1.2 is smaller with "2011

[1] The reference to "directed" anchovy is new in OMP-13, and corresponds to the "anchovy catch" in OMP-08 due to a small amount of anchovy bycatch allowed under OMP-13.
[2] To be quantitative, DIC should be applied to this Bayesian model.

data" than with "2006 data", raising the question that if HS0.9 was deemed "acceptable" with "2006 data", why not so with "2011 data".

- However, given the diagnostic that a smaller portion of the recruitment should be available to the May hydroacoustic survey than the 1+ biomass to the November survey, the assumption of $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9$ year^{-1} is no longer acceptable given the "2011 data", regardless of the assumed stock recruitment relationship (Table 1).
- Assuming the ratios of depletion of OMP-08 under BH1.2 were deemed acceptable and the same "leftward shift" maintained for BH1.2 for Candidate OMP-13, the SPSWG would be agreeing to a 35% chance of the anchovy 1+ biomass falling to 10% of its average 1984-1999 1+ biomass (Figure 4; average of 130 000t) at least once during the next 20 years.

Some possible ways forward are as follows:

1) Work on the basis of the same leftward shift as for OMP-08 in 2006 under HS0.9
   - *Pros*: Consistency with the approach in 2006

     HS0.9 is now relatively more plausible compared to BH1.2 in AIC_c terms than was the case in 2006
   - *Cons*: HS0.9 no longer satisfies model fit diagnostics

     A value of $risk^A$ of 44% compared to 22% in 2006 for BH1.2 seems "unsafe"

2) Work on the basis of the same leftward shift as for OMP-08 in 2006 under BH1.2

   Pros: The value of $risk^A$ drops from 44% under 1) to 35%

   Cons: That 35% value still seems "high"

   Corresponding "leftward shift" was not explicitly agreed during OMP-08 development

3) Explore options to amend the standard anchovy control rule in a manner that reduces catches further when survey results indicate anchovy abundance is low to attempt to reduce $risk^A$ further without compromising OMP performance in other respects too severely.

In considering these (and possibly other) alternatives, the implications for expected catches must also be considered (see Table 3b and also Table A.3). It is of interest that for anchovy, under the three control parameter selection options in Table 3b, the anticipated average anchovy catch hardly changes under the BH1.2 operating model, and even under HS0.9 the changes are slight.. This holds also when the $c_{mxtac}^A = 450$ modification is considered (Table A.3). However there are implications also for anticipated average sardine catches, which become higher under option 2) than option 1) above, given the larger β value for the former.

References

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Table 1. The contributions to the objective function at the posterior mode for a range of combinations of juvenile, $\overline{M}_j^A$, and adult, $\overline{M}_{ad}^A$, natural mortality for models assuming the Hockey Stick stock recruitment relationship with a fixed inflection point, and the Beverton Holt stock recruitment relationship. The ratio of the multiplicative bias in the recruit survey to that in the November survey, k_r^A/k_N^A, and the multiplicative bias in the proportion-at-age 1 in the November survey, k_p^A, are given for diagnostic purposes. The criteria used here and in the past to distinguish "reasonable" from "unrealistic" combinations of natural mortality are:

i) The ratio $k_r^A/k_N^A \in [0.5,1.0]$, as the November spawner biomass survey is expected to have a greater coverage of the full distribution of the resource than the May recruit survey so that the latter should reflect a smaller relative bias, and

ii) The multiplicative bias for values input to the assessment for the proportion-at-age 1 in the November survey, k_p^A, which should not be markedly different from 1. A value much lower than 1 would indicate the 1 year olds are not fully sampled by the survey, while a value much higher than 1 would indicate the 2+ year olds are not fully sampled by the survey; the latter of these seems less likely.

	SR curve	$\overline{M}_j^A$	$\overline{M}_{ad}^A$	AIC$_c$[3]	Posterior	-ln(Likelihood)[4]				-ln(Prior)	k_r^A	k_N^A	k_r^A/k_N^A	k_p^A
						Nov	Egg	Rec	Prop					
2006 data	HS	0.9	0.9	184.11	55.74	-3.82	4.07	7.81	24.28	23.39	1.13	1.45	0.78	0.93
	BH	0.9	0.9	192.13	52.13	-0.93	4.48	6.43	23.06	19.09	1.09	1.40	0.78	0.94
	HS	1.2	1.2	160.92	45.36	-6.71	3.05	5.70	18.71	24.62	0.81	1.36	0.60	0.84
	BH	1.2	1.2	168.96	41.16	-4.38	3.48	4.21	18.15	19.71	0.79	1.32	0.60	0.84
2011 data	HS	0.9	0.9	617.03	283.42	-6.28	6.05	20.22	230.62	32.82	1.25	1.30	1.05	1.28
	BH	0.9	0.9	623.63	279.82	-4.74	6.35	19.18	230.36	28.67	1.21	1.26	1.04	1.26
	HS	1.2	1.2	602.64	276.34	-10.75	5.12	17.65	231.40	32.93	1.17	0.91	0.76	0.75
	BH	1.2	1.2	609.44	272.08	-9.37	5.54	16.55	231.34	28.02	1.16	0.90	0.77	0.73

[3] Although a Bayesian model, AIC$_c$ is used to assist in model selection. AIC$_c$ $=2n - 2\ln L + 2n(n+1)/(D-n-1)$, where n is the number of estimable parameters, D is the number of data points to which the model is fitted and $-\ln L$ is the negative log likelihood (ie excluding the negative log prior from the posterior distribution).

[4] Note that these fits are not comparable between models due to updates in the time series and a revision of the time series of estimates of proportion-at-age 1.

Table 2. The ratio of the percentiles of the distribution of anchovy biomass in 2027 under OMP-08 formulae and in 2032 under Candidate OMP-13 formulae with $c^{A}_{mxtac} = 600$, to a no catch scenario. For HS0.9, a comparison is made to the ratio of the percentiles of the distribution of anchovy biomass in 2027 under OMP-08 to a no-catch scenario. Column 3 gives the percentiles resulting from the application of OMP-08 assuming an alternative (BH1.2) operating model. The final column then tunes the anchovy risk level for Candidate OMP-13 to give percentiles in column 4 as close as possible to those in column 3 (i.e. effect the same "leftward shift"). Shaded cells represent cases for which the predicted ratio (depletion) is more pessimistic than that used for OMP-08.

	Fixed Hockey Stick $\overline{M}^{A}_{j} = \overline{M}^{A}_{ad} = 0.9$ year^{-1}		Beverton Holt $\overline{M}^{A}_{j} = \overline{M}^{A}_{ad} = 1.2$ year^{-1}	
	OMP-08/No Catch	Candidate OMP-13/No Catch	OMP-08/No Catch	Candidate OMP-13/No Catch
α	0.78	0.782	0.78	0.635
β	0.097	0.067	0.097	0.082
$risk^{A}$	<0.10	<0.12		<0.35
10%ile	0.30	0.31	0.11	0.11
20%ile	**0.36**	**0.36**	**0.14**	**0.14**
30%ile	0.40	0.41	0.18	0.17
40%ile	0.43	0.45	0.20	0.20
50%ile	0.47	0.51	0.22	0.24
	"Column 1"	"Column 2"	"Column 3"	"Column 4"

Table 3. Performance statistics for the control parameter values of OMP-08 applied to operating models based on the data available in 2006 are compared to those for two OMP-13 Candidates which keep $c_{mxtac}^{A} = 600$ as used for OMP-08. Results are shown for two operating models (HS0.9 and BH1.2) as fitted first to data to 2006 and then to data to 2011. The two Candidate OMP-13's are distinguished by different choices of control parameter values; these choices are made to achieve the same leftward shift at the corner point of the trade-off curve of the catch compared to the no catch distribution for the 1+ biomass at the end of the projection period as resulted under OMP-08, with the first corresponding to the same "leftward shift" as under the HS0.9 operating model in 2006, and the second to the 2006 shift under the BH1.2 operating model.

a) The risk to the resources[5]. The values in parentheses are the risk levels to which the OMP was tuned to satisfy the criteria for a similar "leftward shift" in projected biomass distribution from a no catch to catch-scenario as accepted for the previous OMP (see de Moor and Butterworth 2010 and main text for details).

Data Assumptions	MP formulae		OMP Control Parameters		$risk^A$		$risk^S$		
			β	α	HS0.9	BH1.2	HS0.9	BH1.2	
2006 data	OMP-08	Risk level tuned to "leftward shift" for HS0.9[6]	0.097	0.78	0.107[7]	0.219[8]	0.183	0.159	"Row 1"
2011 data	Candidate OMP-13 with $c_{mxtac}^{A} = 600$	Risk level tuned to "leftward shift" for HS0.9[9]	0.067	0.782	0.118 (<0.12)	0.436	0.209 (<0.21)	0.188	"Row 2"
		Risk level tuned to "leftward shift" for BH1.2[10]	0.082	0.635	0.087	0.347 (<0.35)	0.221	0.208 (<0.21)	"Row 3"

b) The projected average anchovy and directed sardine catches. The anchovy catches are given for the full year, with the portion assumed caught during the additional season given in parentheses. Note that the first row is not directly comparable to that of Table 3a).

Data Assumptions	MP formulae	OMP Control Parameters		$\overline{C}^A$		$\overline{C}^S$	
		β	α	HS0.9	BH1.2	HS0.9	BH1.2
2011 data	Candidate OMP-13 with $c_{mxtac}^{A} = 600$	0.097	0.78	385 (95)	292 (67)	155	157
		0.067	0.782	385 (95)	292 (67)	127	129
		0.082	0.635	362 (91)	289 (69)	143	145

[5] See page 1 for definitions of "risk".
[6] cf column 1 of Table 2.
[7] These results are slightly different to the results used to choose OMP-08 which had $risk^A = 0.097$ and $risk^S = 0.178$. The difference is due to the set of ε_{2006}^{A} values used. The results used here are preferred to the original ones as they are comparable to those of BH1.2.
[8] There were some difficulties in obtaining MCMC convergence for BH1.2 for the 2006 data, but sensitivity tests to alternative ways of sampling from the chain in relation to high values of *K* did not yield greatly differing *risk* statistics.
[9] cf column 2 of Table 2.
[10] cf column 4 of Table 2.

2006 data

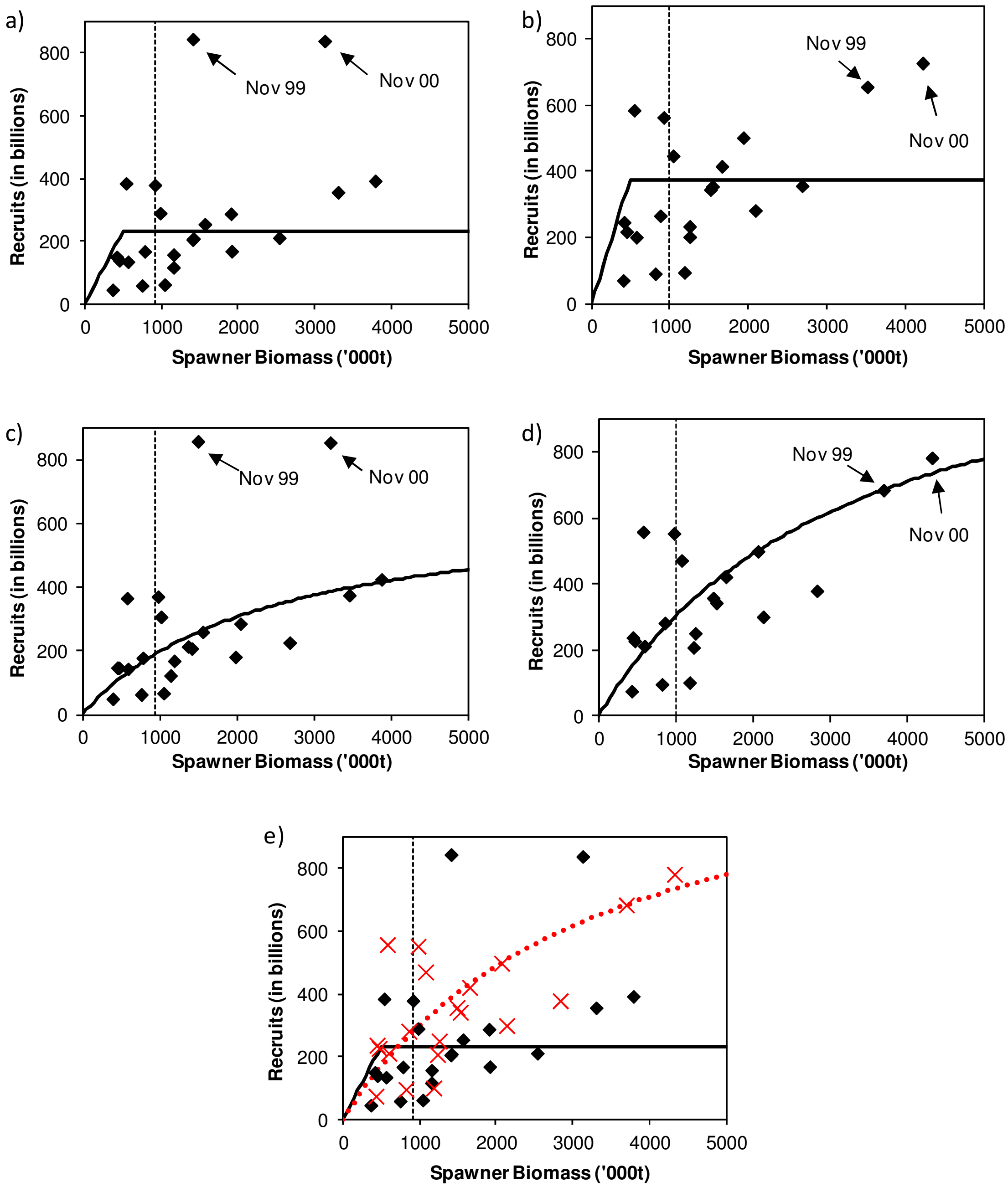


Figure 1. 2006 data: Model estimated stock recruitment relationships for Hockey Stick with fixed inflection point and a) $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$ ("HS0.9") and b) $\overline{M}_j^A = \overline{M}_{ad}^A = 1.2\,\text{year}^{-1}$, and Beverton Holt with c) $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$ and d) $\overline{M}_j^A = \overline{M}_{ad}^A = 1.2\,\text{year}^{-1}$ ("BH1.2"). Plot e) shows both a) (black) and d) (red).

2011 data

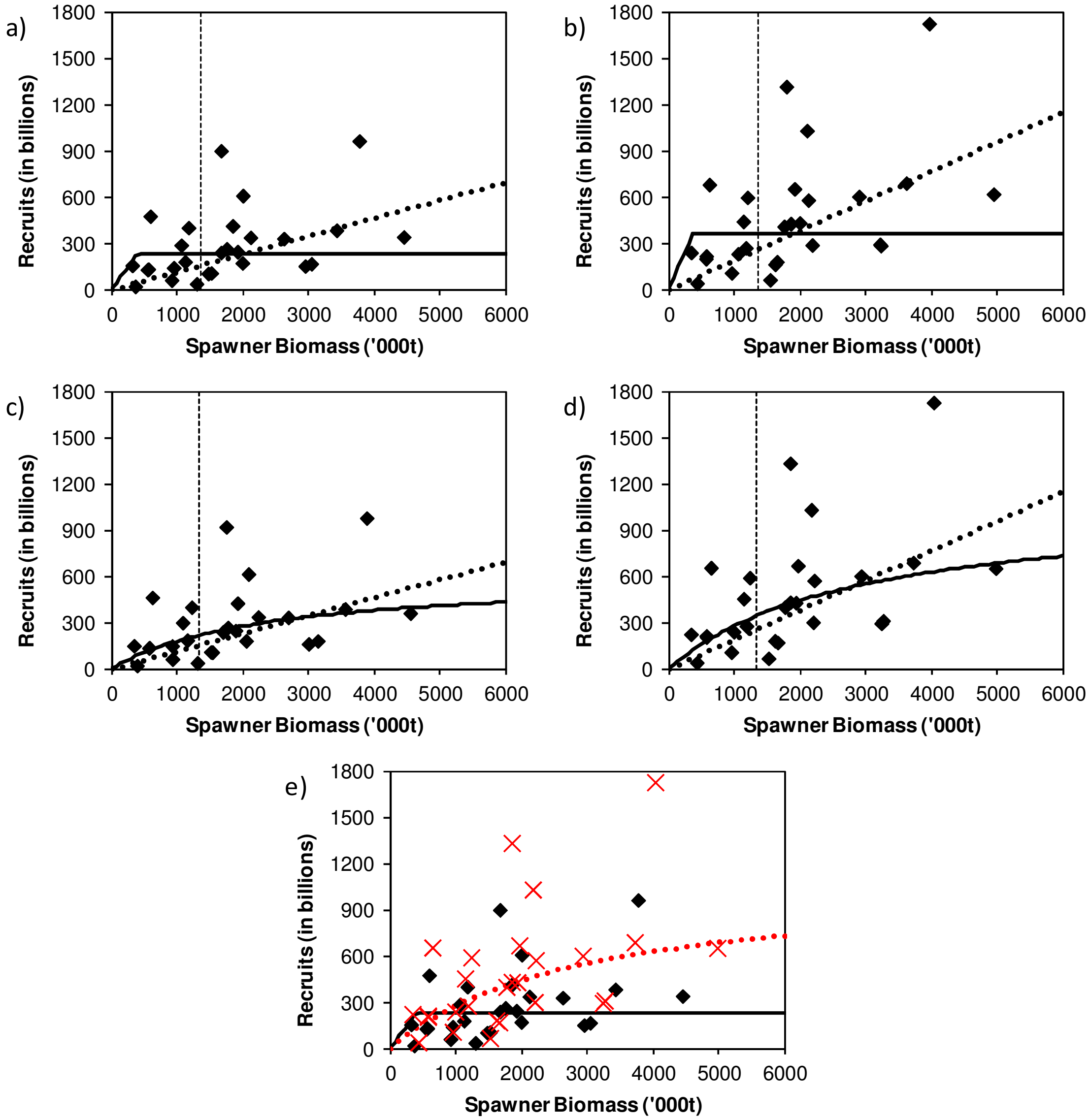


Figure 2. 2011 data: Model estimated stock recruitment relationships for Hockey Stick with fixed inflection point and a) $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$ ("HS0.9") and b) $\overline{M}_j^A = \overline{M}_{ad}^A = 1.2\,\text{year}^{-1}$, and Beverton Holt with c) $\overline{M}_j^A = \overline{M}_{ad}^A = 0.9\,\text{year}^{-1}$ and d) $\overline{M}_j^A = \overline{M}_{ad}^A = 1.2\,\text{year}^{-1}$ ("BH1.2"). Plot e) shows both a) (black) and d) (red).

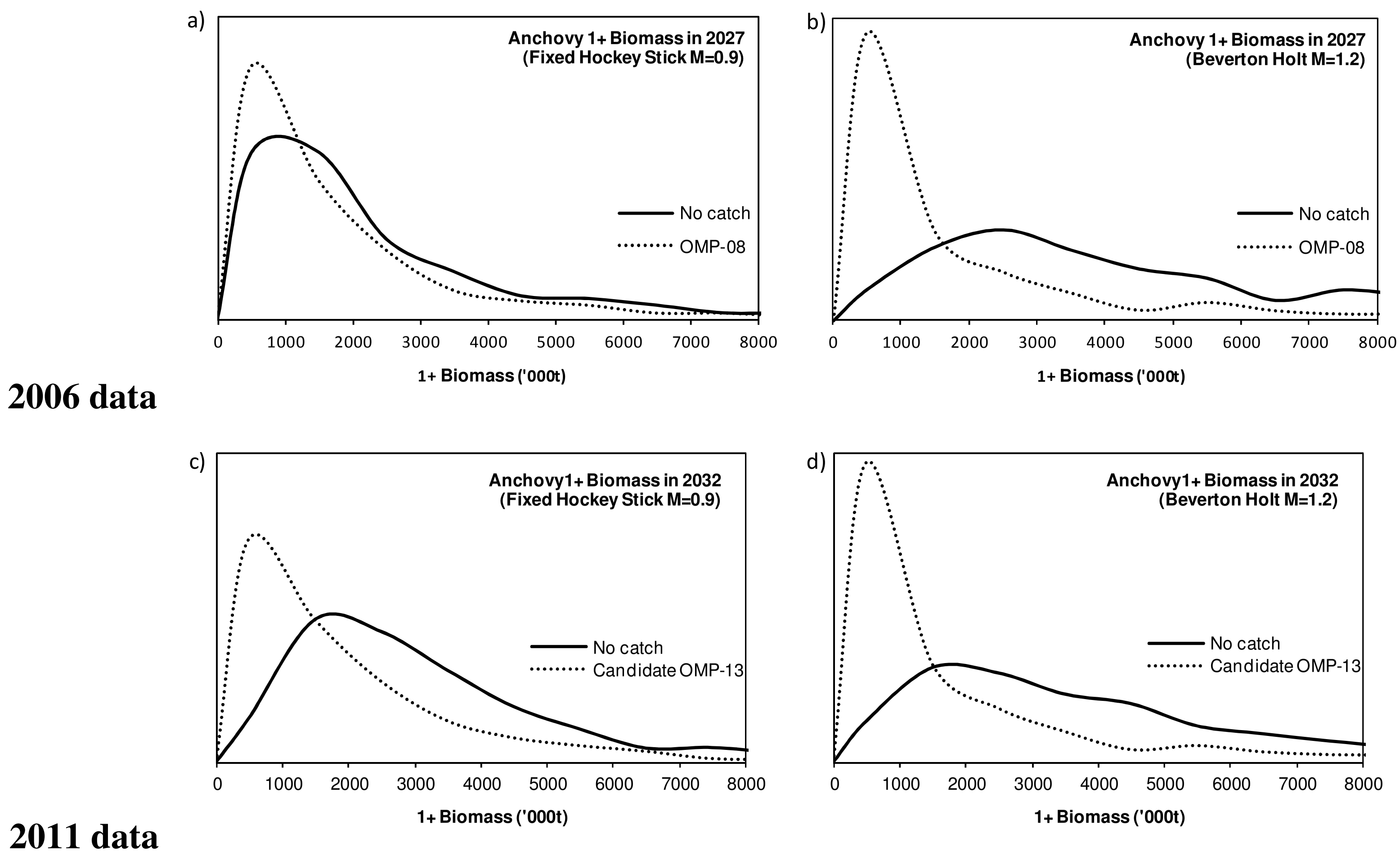
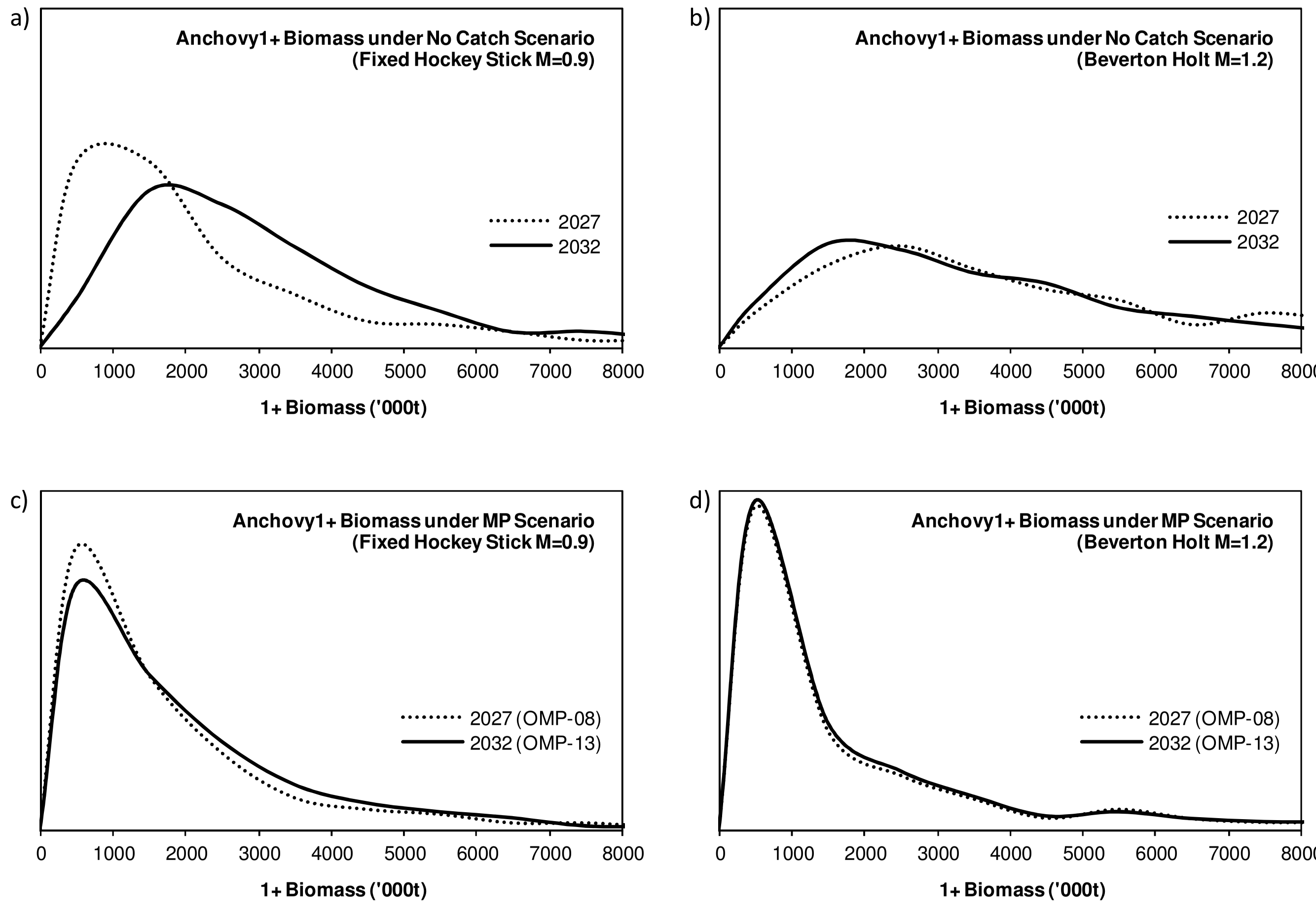


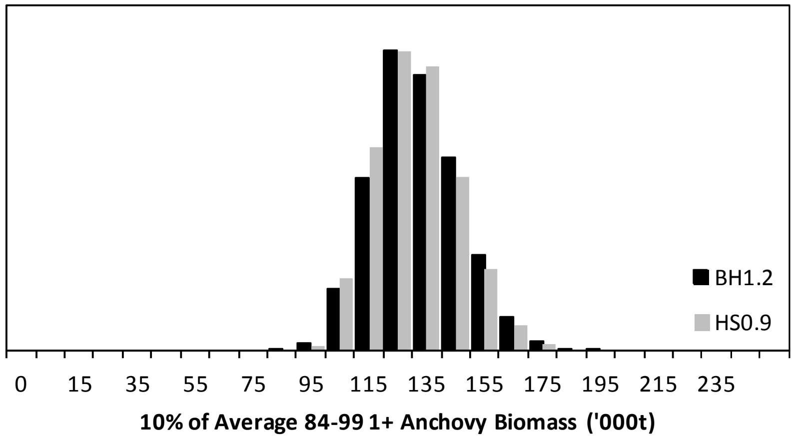
Figure 3a. Comparison of anchovy biomass distribution in the final projection year under a no catch scenario and a) OMP-08 ($\alpha = 0.78$, $\beta = 0.097$) assuming the base case operating model HS0.9 with "2006 data", b) OMP-08 ($\alpha = 0.78$, $\beta = 0.097$) assuming BH1.2 with "2006 data", c) Candidate OMP-13 (with $c^A_{mxtac} = 600$) tuned to give the same "leftward shift" for "2011 data" as under the 2006 HS0.9 operating model for OMP-08 ($\alpha = 0.782$, $\beta = 0.067$), and d) Candidate OMP-13 (with $c^A_{mxtac} = 600$) ($\alpha = 0.635$, $\beta = 0.082$) tuned to give the same "leftward shift" for "2011 data" as under the BH1.2 operating model and using the control parameter values chosen for OMP-08.



No Catch Scenario

MP Scenario

Figure 3b. The same distributions as given in Figure 3a, paired differently. Comparison of anchovy biomass distribution in the final projection year under a) a no catch scenario assuming HS0.9 as the operating model, b) a no catch scenario assuming BH1.2 as the operating model, c) OMP-08 and Candidate OMP-13 (with $c^{A}_{mxtac} = 600$) assuming HS0.9 as the operating model, and d) OMP-08 and Candidate OMP-13 (with $c^{A}_{mxtac} = 600$) assuming BH1.2 as the operating model, where the approaches used to obtain similar "leftward shifts" for the Candidate OMP-13 variants are explained in the previous caption.



Figu**re 4.** The posterior distribution of the anchovy risk threshold (10% of the average 1984-1999 1+ biomass) from the assessment using the 2011 data.

Appendix: Further results

Table A.1 (an extension of Table 2). The ratio of the percentiles of the distribution of anchovy biomass in 2027 under OMP-08 formulae and in 2032 under Candidate OMP-13 formulae (with $c^A_{mxtac} = 600$ or $c^A_{mxtac} = 450$). Shaded cells represent cases for which the predicted ratio (depletion) is more pessimistic than that for the column to which a comparison is being made.

i) OMP-08 (column 2) was tuned to closely match the depletion ratio at the 20 percentile in OMP-04 (column 1), assuming the HS0.9 operating model.
ii) Candidate OMP-13 is tuned to closely match the depletion ratio at the 20 percentile in OMP-08, assuming the HS0.9 operating model (columns 3 and 4).
iii) OMP-08 is tuned to closely match the depletion ratio at the 20 percentile in OMP-04, assuming the BH1.2 operating model (column 5).
iv) Candidate OMP-13 is tuned to closely match the depletion ratio at the 20 percentile in column 5 (column 6), assuming the BH1.2 operating model.
v) The depletion ratio implied by OMP-08 (column 2) assuming the BH1.2 operating model is given in column 7.
vi) Candidate OMP-13 is tuned to closely match the depletion ratio implied by OMP-08, assuming the BH1.2 operating model (columns 8 and 9).

	Fixed Hockey Stick $\overline{M}^A_j = \overline{M}^A_{ad} = 0.9$ year^{-1} (HS0.9)				Beverton Holt $\overline{M}^A_j = \overline{M}^A_{ad} = 1.2$ year^{-1} (BH1.2)				
	OMP-04/No Catch	OMP-08/No Catch	OMP-13 ($c^A_{mxtac} = 600$)/ No Catch	OMP-13 ($c^A_{mxtac} = 450$)/ No Catch	OMP-08/No Catch	OMP-13 ($c^A_{mxtac} = 600$)/ No Catch	OMP-08/No Catch	OMP-13 ($c^A_{mxtac} = 600$)/ No Catch	OMP-13 ($c^A_{mxtac} = 450$)/ No Catch
α		0.78	0.782	0.784	0.34	0.247	0.78	0.635	0.636
β		0.097	0.067	0.070	0.136	0.093	0.097	0.082	0.082
$risk^A$		<0.10	<0.12	<0.12	<0.085	<0.188		<0.35	<0.35
10%ile	0.25	0.30	0.31	**0.32**	0.28	0.25	0.11	0.11	0.11
20%ile	**0.37**	**0.36**	**0.36**	**0.36**	**0.37**	**0.37**	**0.14**	**0.14**	**0.14**
30%ile	0.45	0.40	0.41	**0.42**	0.41	0.41	0.18	0.17	0.17
40%ile	0.56	0.43	0.45	**0.46**	0.44	0.46	0.20	0.20	0.20
50%ile	0.58	0.47	0.51	**0.52**	0.47	0.48	0.22	0.24	0.24
	"Column 1"	"Column 2"	"Column 3"	"Column 4"	"Column 5"	"Column 6"	"Column 7"	"Column 8"	"Column 8"

Table A.2 (an extension of Table 3a). The risk to the resources under MPs with the same formula as OMP-08, Candidate OMP-13 (with $c^A_{mxtac} = 600$ and $c^A_{mxtac} = 450$) and Interim OMP-13 for alternative operating model assumptions. Results are shown for two operating models (HS0.9 and BH1.2) as fitted first to data to 2006 and then to data to 2011. The values in parentheses are the risk levels to which the OMP was tuned to satisfy the criteria for a similar "leftward shift" in the projected biomass distribution from a no catch to catch-scenario as accepted for the previous OMP (see de Moor and Butterworth 2010 and main text for details). The **bold** cells are key results to which reference is made in the text and which appear in Table 3.

Data Assumptions	MP formulae	Basis to select control parameter values	OMP Control Parameters		$risk^A$		$risk^S$	
			β	α	HS0.9	BH1.2	HS0.9	BH1.2
2006 data	OMP-08	Risk level tuned to "leftward shift" for HS0.9	0.097	0.78	**0.107**	**0.219**	**0.183**	**0.159**
		Risk level tuned to "leftward shift" for BH1.2[11]	0.136	0.34	0.031	0.083 (<0.085)	0.196	0.179 (<0.18)
2011 data	Candidate OMP-13 with $c^A_{mxtac} = 600$	Risk level tuned to "leftward shift" for HS0.9	0.067	0.782	**0.118** (<0.12)	0.436	**0.209** (<0.21)	0.188
		OMP-08 values	0.097	0.78	0.118	0.433	0.276	0.255
		Risk level tuned to "leftward shift" for BH1.2	0.082	0.635	0.087	**0.347** (<0.35)	0.221	**0.208** (<0.21)
		Same values as follow for OMP-08 formulae, but with control parameters chosen to satisfy 2006 data and BH1.2	0.136	0.34	0.024	0.208	0.329	0.330
		Risk level tuned to "leftward shift" of HS0.9, for BH1.2[12]	0.093	0.247	0.018	0.186 (<0.188)	0.212	0.208 (<0.21)
	Candidate OMP-13 with $c^A_{mxtac} = 450$	Risk level tuned to "leftward shift" for HS0.9[13]	0.070	0.784	0.118 (<0.12)	0.430	0.209 (<0.21)	0.193
		Risk level tuned to "leftward shift" for BH1.2[14]	0.082	0.636	0.086	0.347 (<0.35)	0.222	0.207 (<0.21)
	Interim OMP-13	Risk level tuned to "leftward shift" for HS0.9, but with $c^A_{mxtac} = 350$, and applied to BH1.2	0.090	0.321	0.021	0.197 (<0.20)	0.212	0.209 (<0.21)

[11] cf column 5 of Table A.1
[12] cf column 6 of Table A.1
[13] cf column 4 of Table A.1
[14] cf column 9 of Table A.1

Table A.3 (an extension of Table 3b). The projected average directed anchovy and sardine catches under Candidate OMP-13 (with $c^A_{mxtac} = 600$ or $c^A_{mxtac} = 450$) and Interim OMP-13 for alternative operating model assumptions, corresponding to the same control parameters as considered in Table A.2. The anchovy catches are given for the full year, with the portion assumed caught during the additional season given in parentheses. The **bold** cells are key results to which reference is made in the text.

Data Assumptions	MP formulae	OMP Control Parameters		$\overline{C}^A$		$\overline{C}^S$	
		β	α	HS0.9	BH1.2	HS0.9	BH1.2
2011 data	Candidate OMP-13 with $c^A_{mxtac} = 600$	0.067	0.782	**385 (95)**	**292 (67)**	**127**	**129**
		0.097	0.78	385 (95)	292 (67)	155	157
		0.082	0.635	362 (91)	**289 (69)**	143	**145**
		0.136	0.34	294 (82)	265 (69)	188	188
		0.093	0.247	266 (81)	247 (71)	158	158
	Candidate OMP-13 with $c^A_{mxtac} = 450$	0.070	0.784	373 (93)	280 (67)	131	132
		0.082	0.636	356 (91)	**281 (69)**	144	**145**
	Interim OMP-13	0.090	0.321	287 (82)	259 (70)	154	154

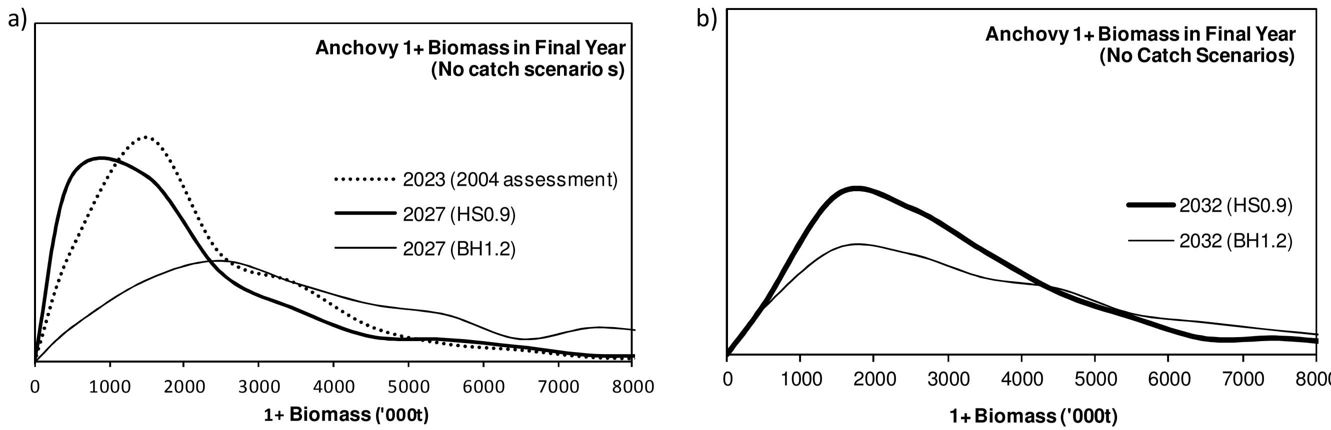


Figure A.1. Comparison of anchovy biomass distributions in the final projection year under a no catch scenario using a) the 2004 operating model (HS0.9) and HS0.9 and BH1.2 operating models with "2006 data", and b) HS0.9 and BH1.2 operating models with "2011 data".

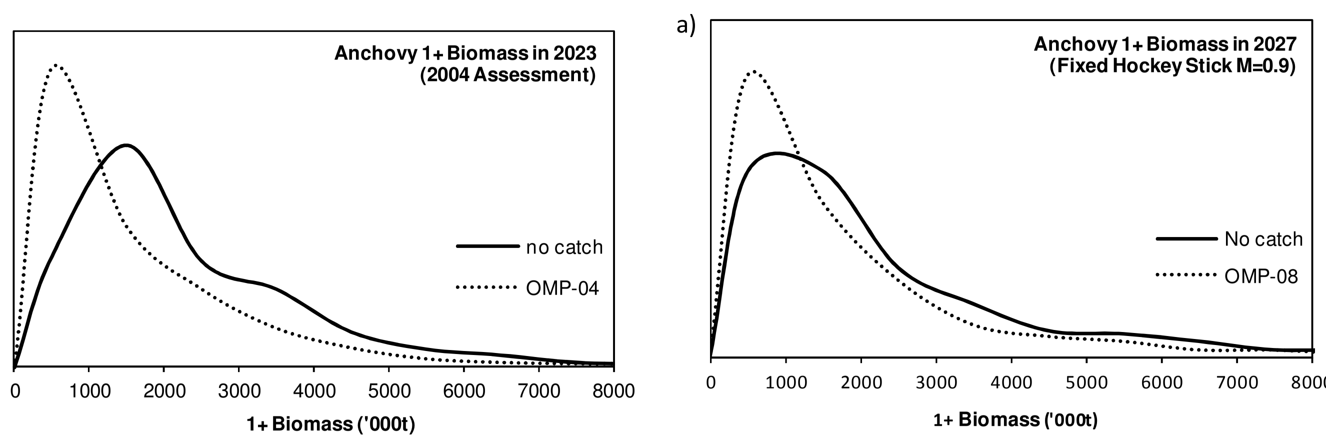


Figure A.2. Comparison of anchovy biomass distributions in the final projection year under a no catch scenario and a) OMP-04 or b) OMP-08, all under the assumption of a HS0.9 operating model.